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Neurological soft signs: Effects of trait schizotypy, psychological distress and auditory hallucination predisposition

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ABSTRACT

Schizotypy is regarded as a trait vulnerability for psychotic disorders, yet alone is insufficient for development of a diagnosable disorder. Additional symptoms and psychological distress are necessary for help seeking and transition from an at risk mental state to a clinical diagnosis. The present study investigated the interaction between trait schizotypy, state auditory verbal hallucination (AVH) predisposition, distress and handedness for the expression of neurological soft signs (NSS), a neurodevelopmental vulnerability factor for psychosis. Cluster analysis formed schizotypy groups statistically across the dimensions captured by the SPQ. It was hypothesized that schizotypy and AVH predisposition would interact, resulting in significantly greater NSS. Psychological distress and handedness were hypothesized to be significant covariates, accounting for some variance in the expression of NSS between the groups. A sample of University students ($n = 327$) completed the Schizotypal Personality Questionnaire, Launay-Slade Hallucination Scale, General Health Questionnaire and the Neurological Evaluation Scale (NES). Cluster Analysis revealed four schizotypy groups. Distress was not a significant covariate in any analysis. As expected, those with high overall schizotypy and high AVH predisposition expressed significantly greater Motor-Coordination NSS compared to those with high schizotypy and low AVH predisposition. Within the Mixed Interpersonal and Cognitive-Perceptual Schizotypy cluster, those with low AVH predisposition expressed significantly more Motor-Coordination NSS than those with high AVH predisposition. These findings suggest motor coordination NSS are detectable in schizotypy, and AVH predisposition appears to interact with these traits. This study highlights the importance of considering both trait and subclinical state risk factors when investigating risk for psychosis.

1. Introduction

Schizotypy is a multidimensional construct which represents a heightened vulnerability for psychotic disorders (Kwapil et al., 2013; Salokangas et al., 2013). The schizotypal personality trait is characterized by unusual experiences of perception, oddities in speech and behavior, disorganised and disrupted thought content, paranoia/suspiciousness and flattened affect (Kwapil and Barrantes-Vidal, 2015). The multidimensional structure of schizotypy is believed to mirror that of schizophrenia, with associated phenomena grouped through factor analysis into positive, negative, and disorganised traits (Raine et al., 1994; Stefanis et al., 2004; Mason, 2015). As a result, schizotypy has become central in the investigation of psychosis risk. However, schizotypal trait is not itself sufficient for conversion to psychosis; transition to psychotic disorders requires multiple psychopathological risk factors (Barrantes-Vidal et al., 2015). Schizotypy has been found to consistently account for more than half the variance associated with subclinical psychotic phenomena, but does not account for all of it (Rössler et al., 2013). Therefore other factors must combine with schizotypal dimensions to contribute to the development of psychotic disorders. As such, research has focused on a multiple hit model for psychosis risk (e.g. Keshavan, 1999; McDonald and Murray, 2000), where neurodevelopmental and trait biological risk factors interact with state risk factors (such as psychological distress, and psychotic-like experiences (PLEs; e.g. auditory hallucinations)), to increase risk for transition. Trait factors here are perceived to be stable and reasonably consistent across time and situations. Trait and neurodevelopmental factors are often present from birth, however it may only be possible to measure or capture them at different points during development. On the other hand, state risk factors fluctuate according to internal or external factors. Trait and state factors can then be combined to gain a perspective of an individual's stable vulnerability as well as their current and transient vulnerability as a result of fluctuating experiences such as distress. Distress can be triggered by events in an individual's environment or other subjective psychological experiences. The presentation of *trait* schizotypy with *state* auditory verbal hallucination (AVH) predisposition is one combination which may lead to the emergence of additional psychological vulnerabilities including psychological distress (Cella et al., 2008), disruptions in metacognitive processes (Barkus et al., 2010), and delusion formation

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(Krabbendam et al., 2005). The greater the number of additional "hits" an individual encounters, the higher the risk of transition to psychotic disorders, with risk increasing in a dose-dependent fashion (Binbay et al., 2012; Pedersen and Mortensen, 2001). The "hit" may lead to the expression of state risk factors, or may indeed be the exacerbation or presence of compounding state risk factors operating against trait vulnerability.

It is recognized that schizotypy has neurodevelopmental origins (Raine, 2006), therefore consideration needs to be given to whether other neurodevelopmental factors are associated with schizotypy. One such neurodevelopmental factor is neurological soft signs (NSS). The presence of NSS along the psychosis continuum has provided important insights into risk for psychotic illness (Bombin et al., 2005; Dazzan and Murray, 2002). NSS refer to subtle neurological irregularities that are not a component of a properly defined neurological syndrome, but rather are believed to reflect inefficiencies in the communication and processing between different brain regions (Chan and Gottesman, 2008). Research has linked NSS to the atrophy and abnormal activation of the cerebellum and inferior frontal gyrus, among other areas (Zhao et al., 2014). Phenotypically, NSS are observed as abnormalities in motor functions, sensory functions, disinhibition and complex motor sequencing (Buchanan & Heinrichs, 1989). The Neurological Evaluation Scale (NES; Buchanan and Heinrichs, 1989) is one of the more common measures of NSS. Factor analyses of the scale have demonstrated solutions ranging from one to five factors (i.e. Mohr et al., 1996; Emsley et al., 2005; Sanders et al., 2005). However, most analyses generally reflect a separation between motor and sensory dysfunction (i.e. Keshavan et al., 2003; Sanders et al., 2000, 2005).

There is a consensus that NSS are significantly more prevalent in schizophrenia patients compared to the general population (Zhao et al., 2013). NSS are consistently found in first episode medication-naïve patients (Mayoral et al., 2008; Zabala et al., 2006), their relatives (Gabalda et al., 2008; Mechri et al., 2009), at-risk mental state (ARMS) patients (Tamagni et al., 2013), and those with the schizotypal personality trait (Barkus et al., 2006; Barrantes-Vidal et al., 2003; Chan et al., 2010b; Kaczorowski et al., 2009). Collectively these results suggest that NSS are a neurodevelopmental marker inherent to psychosis risk (Bachmann et al., 2005, 2014). In schizophrenia NSS are related to the severity of negative symptoms and disorganised behavior (i.e. Mohr et al., 1996; Arango et al., 2000), however are not as conclusively linked to positive symptomatology (i.e. Browne et al., 2000). Concerning schizotypy, positive correlations have been documented between Motor Coordination NSS and overall schizotypy (i.e. Chan et al., 2010b; Mechri et al., 2010); however some studies report non-significant associations (i.e. Bollini et al., 2007; Prasad et al., 2009; Theleritis et al., 2012). Likewise, positive associations have been reported between negative schizotypy and greater overall NSS (i.e. Bollini et al., 2007; Kaczorowski et al., 2009; Theleritis et al., 2012). This is similar to the association found between the negative symptoms of schizophrenia and NSS, however again this finding is not consistent across schizotypal studies (Mechri et al., 2010).

Differences in research design, including the schizotypy and NSS scales used, along with the status of participants (healthy controls versus healthy relatives of schizophrenia patients), may contribute to disparities in findings. It is also possible that NSS are related to another state component of psychosis risk such as AVH predisposition, which is conceptually separate from, but related to, schizotypy. Supporting this assertion are findings of NSS varying according to schizophrenia clinical course (e.g. Bachmann et al., 2005; Prikryl et al., 2012), suggesting they could comprise both state and trait features (e.g. Bachmann et al., 2014). It is proposed that NSS, as neurodevelopmental markers for psychosis risk, would be present in increased levels in those with a trait risk for psychosis (i.e. those with schizotypal traits). Indeed, it is possible that NSS may contribute to the expression of schizotypal traits in an individual. NSS may fluctuate around this heightened baseline depending on co-occurring state risk factors, similar to the variation in NSS seen as a result of clinical course in schizophrenia (Bachmann et al., 2005; Prikryl et al., 2012). Those with heightened NSS may be sensitive to additional taxing from the presence of high emotional states such as distress. The distress may perturb an already taxed system to lead to increased inefficiency and expression of NSS. Those with increased levels of schizotypy also demonstrate poor emotion regulation (for review, see Giakoumaki, 2016) and consequent higher levels of depression and anxiety (e.g. Lewandowski et al., 2006). Indeed, those with schizotypal traits and co-occurring axis 1 psychiatric disorder (most frequently mood disorders and ADHD) have documented significantly greater NSS compared to schizotypy alone (Keshavan et al., 2008; Prasad et al., 2009). Therefore high levels of distress are related to both schizotypy and heightened NSS. To account for this, it makes sense to control for general levels of distress in the current study. Distress, a state variable, is hypothesized to tax an already inefficient neurological system, to result in further disruptions in NSS. Thus state distress *may* exert a co-varying effect on the expression of neurodevelopmental risk variants for psychosis, and is hypothesized to account for some of the differences in NSS expression in schizotypy.

Another commonly reported biological marker along the psychosis continuum is reduced hemispheric symmetry, whereby the typical left hemisphere preference for language functions (e.g. Josse and Tzourio-Mazoyer, 2004) is either reversed or absent in individuals with schizophrenia (e.g. Kawasaki et al., 2008; Bleich-Cohen et al., 2009) and schizotypy (e.g. Mohr et al., 2003; Suzuki and Usher, 2009). In clinical studies handedness is often used as a proxy for hemispheric specialization, with right-handedness usually being indicative of left hemisphere language preference and right hemisphere visual facial processing preference (e.g. Bourne, 2006; Josse and Tzourio-Mazoyer, 2004). The observed reduction in hemispheric asymmetry for those expressing schizotypal traits has implications in the current study. Accordingly, handedness will be assessed and controlled for in order to accurately investigate differences between those expressing higher levels of schizotypal dimensions compared to those who are not.

Previous studies have made use of correlational analyses where one dimension of schizotypy is often considered to be related to one dimension of NSS. However, the dimensions of schizotypy are strongly related to one another and do not occur in isolation. Indeed there is position that an individual who scores highly on all dimensions of schizotypy could be viewed at heightened risk to those who, for example, merely express the negative dimension of schizotypy. An alternative to the previous correlational approach to schizotypy is to utilize cluster analysis to form groups statistically across the dimensions of schizotypy. This allows for individuals to be elevated on more than one schizotypy dimension simultaneously (Suhr and Spitznagel, 2001), therefore complementing correlational approaches rather than conforming to a categorical approach to psychosis risk. Cluster analysis clarifies inconsistencies evidenced by correlational approaches where individuals may have a mixed profile of positive and negative schizotypal dimensions, rather than being elevated on one dimension only (see Barrantes-Vidal et al., 2010 for further discussion). Since the current research is interested in the elevated expression of schizotypy across the schizotypal dimensions this approach is believed to be appropriate. Previous schizotypy research has found the number of clusters to vary from three to four-group cluster solutions (e.g. Suhr and Spitznagel, 2001; Aguilera Ruíz et al., 2008; Barrantes-Vidal et al., 2003; Goulding, 2005). Most often, clusters were characterized as: high overall schizotypy, positive schizotypy (with unusual perceptual experiences and cognitive disorganization characteristics), negative schizotypy (with introverted and anhedonic characteristics), and low overall schizotypy. The current study is using the Schizotypal Personality Questionnaire (SPQ; Raine, 1991) to form clusters, and the number of clusters yielded will be based on model fit. In the context of NSS and schizotypy the cluster approach has been used once previously (Barrantes-Vidal et al., 2003). The findings of this study only reached trend level significance, which may have been due to the use of an ad hoc NSS scale which is to our knowledge, not a validated NSS measure

(Obiols et al., 1999). Consequently, adopting cluster analysis in combination with a more robust measure of NSS may highlight differences attributable to the dimensions of schizotypy. The current study is using the Neurological Evaluation Scale (NES; Buchanan and Heinrichs, 1989): one of the most widely used measures of NSS within the psychosis literature (e.g. Compton et al., 2006; Chan et al., 2010a; Sewell et al., 2010). Therefore the research from this study can be more easily compared with existing research in the field.

The purpose of the current study was to investigate the interaction between trait schizotypy and state AVH predisposition (i.e. multiple "hits") on NSS. It was expected that one of the clusters would be characterized by elevations in all schizotypal dimensions, whilst another would be characterized by reductions in all schizotypal dimensions. Based on previous research (e.g. Suhr and Spitznagel, 2001; Aguilera Ruíz et al., 2008; Barrantes-Vidal et al., 2003; Goulding, 2005) the configuration of the other clusters was predicted to be: predominantly negative schizotypy, and predominantly positive schizotypy. Additionally, this study aimed to determine whether state psychological distress and/or atypical handedness (as a proxy for reduced hemispheric asymmetry) also accounted for the expression of NSS. Significant differences between schizotypy clusters were hypothesized for psychological distress, handedness and AVH predisposition. Concerning NSS, based on previous correlational research (e.g. Bollini et al., 2007; Chan et al., 2010b; Mechri et al., 2010; Theleritis et al., 2012) significantly greater NSS was predicted in the cluster that is characterized by elevated scores on multiple schizotypy dimensions. We also hypothesized that distress and handedness would have co-varying effects, accounting for a significant proportion of variance between schizotypal clusters in the expression of NSS. Finally it was hypothesized that AVH predisposition, as an additional risk component under a multiple hit model, would be associated with greater NSS.

2. Method

2.1. Participants

Participants were undergraduate Psychology students who participated for course credit ($n = 327$, mean age = 21.5 (SD 6.8), 72% female). Participants were screened for previous head injury/neurological abnormality, history of psychotic illness, diagnosis of a learning disorder or insufficient knowledge of the English language.

2.2. Measures

2.2.1. Neurological examination

The Neurological Evaluation Scale (NES; Buchanan and Heinrichs, 1989) comprises 26 items and was scored according to the original instructions; 0 (no abnormality), 1 (mild but definite impairment), or 2 (present), with total scores ranging between 0 and 76. Fourteen of the items are assessed bilaterally. For the purpose of this study, bilateral right and left items were summed as has been done in previous studies (Bollini et al., 2007; Theleritis et al., 2012). NSS are divided on the basis of dysfunction in three functional areas of interest: Sensory Integration (SI; audio-visual integration, stereogenesis, graphesthesia, extinction, right-left orientation), Motor-Coordination (MC; tandem walk, rapid alternating movements, finger-thumb opposition, finger-to-nose test) and the Sequencing of Complex Motor Acts (SCMA; fist-ring test, fist-edge-palm test, Ozeretski test, rhythm tapping). Other items included in the scale which contribute to the total score include: synkinesis, convergence, gaze impersistence, glabellar reflex, snout reflex, grasp reflex, suck reflex. Handedness was assessed as a standard part of the NES, with respondents asked their hand preference when performing a series of 9 different tasks (i.e. writing, opening the lid of a jar, brushing their teeth). Handedness was determined if they indicated a preference for the same hand on 7 or more tasks. If preference for one hand was indicated for <7 tasks then mixed handedness was assigned. Given that non-right handedness is associated with schizotypy and the psychosis continuum in general (Somers et al., 2009), this variable is expected to impact on cluster differences and therefore will act as a covariate in analyses. All statistical analyses were conducted using the subscales as well as the total NES score.

2.2.2. Measures of schizotypy, AVH predisposition, psychological distress and verbal IQ

The Schizotypal Personality Questionnaire (SPQ; Raine, 1991) consists of 74 items requiring yes or no responses. Items are scored together to make a total score and three dimensions (Interpersonal Schizotypy (negative schizotypy), Cognitive-Perceptual Schizotypy (positive schizotypy), Disorganised Schizotypy). Only the dimensions were used to derive participant cluster membership.

The Launay-Slade Hallucination Scale (LSHS; Launay and Slade, 1981) is made up of 12 items measuring presence of clinical and subclinical hallucinatory experiences. Higher scores reflect a greater predisposition to these experiences. The LSHS is designed to be used in both clinical (e.g. Kot and Serper, 2002) and general population (e.g. Kot et al., 2000) samples. The LSHS will not be used to form cluster groupings given that it is a state measure of AVH predisposition and is changeable over time, unlike trait schizotypy.

The General Health Questionnaire (GHQ; Goldberg and Hillier, 1979) is designed to measure state psychological distress, with higher scores representative of a greater experience of distress. The scale consists of 28 items rated from 0 to 3. In non-clinical samples responses on the GHQ have been highly associated with other state measures of distress such as depression and anxiety (e.g. Hotopf et al., 1998).

Verbal intelligence was measured using the National Adult Reading Test (NART; Nelson, 1982).

2.3. Procedure

Ethical approval was obtained from the Human Research Ethics Committee at the University of Wollongong (approval number HE12/362). Participants were given access to study information via a university-run research participation system. Once they signed up to the study informed consent was obtained online (with options to contact the researcher if required). Questionnaires were also completed online via a survey link. They were then invited to participate in the second stage of the study, and informed consent for this stage was obtained in writing. The NES and NART were completed during this time, with researchers unaware of participants' schizotypy cluster classification.

Four trained evaluators administered the NES and NART to participants. To assess inter-rater reliability raters jointly examined 20 participants, whereby one rater was paired up with each of the remaining raters. This procedure ensured consistency in ratings. The correlation coefficients for subscale and total scores ranged from 0.71 to 0.98.

2.4. Statistical analysis

Descriptive statistics were performed in SPSS 19 (IBM, 2010). Random missing data accounted for 4.1% of all data, and were excluded case-wise for all analyses. Normality of the data was checked using values of Skewness and Kurtosis. All values were within the ± 2 limit, therefore parametric analyses were considered acceptable (George and Mallery, 2010). Given the similarities in the types of experiences focused on in the LSHS and Cognitive-perceptual subdomain of the SPQ, Pearson correlations were calculated initially to ensure there is some degree of distinction between these variables. SPQ subscale scores were converted into z-scores to normalize the data. Schizotypy clusters were derived using K-means iterative cluster analysis with Cognitive-Perceptual, Interpersonal, and Disorganised schizotypy scores. LSHS was also used initially to form clusters, however fit was poor and therefore this variable was removed. Following previous schizotypy cluster studies a 4-group cluster solution was forced (e.g. Barrantes-Vidal

et al., 2003, 2010; Suhr and Spitznagel, 2001). This solution was compared to a 3-group cluster solution (reflective of SPQ dimensions), however the 4-group cluster solution emerged as superior in terms of fit, as indicated by a Wilks' Lambda of 0.069 (4 cluster solution), versus 0.142 (3 cluster solution).

Demographic schizotypy group differences were investigated using Independent Samples *t*-tests for continuous variables and Chi-Squared tests for categorical variables. Any significant differences at the $p = 0.05$ level (one-tailed) that may have accounted for NSS findings were controlled in subsequent analyses as covariates. To investigate the effect of schizotypy cluster group membership and AVH predisposition on NSS, LSHS total score was split into two groups either side of the mean. Those scoring 5 or higher were in the high group ($n = 109$), whilst scores from 0 to 4 were considered low ($n = 218$). A one-tailed Multivariate Analysis of Covariance (MANCOVA) was utilized to investigate group differences in the expression of NSS. In this analysis schizotypy cluster groups and LSHS mean split groups were independent variables, and NES total and subscale scores were dependent variables.

3. Results

3.1. Correlations between SPQ and LSHS

Pearson's correlations showed significant ($p < 0.001$) associations between LSHS and SPQ Total ($r = 0.619$), Cognitive-perceptual ($r = 0.651$), Interpersonal ($r = 0.406$) and Disorganised ($r = 0.514$) subscales. Therefore the strength of the relationship between the LSHS and SPQ Total, Cognitive-perceptual, and Disorganised subdomains is of moderate strength, whilst the association between LSHS and the Interpersonal SPQ subdomain is weak (Mukaka, 2012).

3.2. Schizotypy clusters

K-means iterative cluster analysis produced a four-cluster solution across the Cognitive-Perceptual, Interpersonal and Disorganised dimensions of the SPQ. A MANOVA with cluster assignment as the Independent variable and SPQ factor scores as the Dependent variables was then used to obtain a discriminative index score. Wilks' Lambda (0.069) was significant ($p < 0.000$), which demonstrated that only 6.9% of the total variance was left unexplained. Descriptive statistics of the four clusters are presented in Table 1, with names of each cluster corresponding to SPQ characteristics.

3.3. Demographic characteristics of schizotypy clusters

No significant differences were found between schizotypy clusters on sex, age, Verbal IQ, living arrangements, use of health services, or presence of a diagnosed learning disorder. Significant differences did exist between clusters on handedness ($\chi^2 = 22.592$, $df = 6$, $p = 0.001$), AVH predisposition ($F(3, 323) = 47.615$, $p < 0.000$), psychological distress ($F(3, 323) = 22.898$, $p < 0.000$), schizotypy total score ($F(3, 323) = 553.594$, $p < 0.000$) and the schizotypy subscales: Cognitive-Perceptual ($F(3, 323) = 177.139$, $p < 0.000$), Interpersonal ($F(3, 323) = 252.996$, $p < 0.000$), and Disorganised ($F(3, 323) = 337.496$, $p < 0.000$). These differences are presented in Table 1. The cluster characteristics for the first and third clusters were straightforward, and thus were named High overall Schizotypy and Low overall Schizotypy respectively. The characteristics of the second and fourth clusters were more mixed. After revision, it was decided to name these clusters Disorganised Schizotypy dominant and Mixed Interpersonal and Cognitive-Perceptual Schizotypy. The word 'dominant' is used with the Disorganised Schizotypy cluster to remind the reader that this cluster is not pure in its configuration given that it also has average levels of Interpersonal and Cognitive-Perceptual Schizotypy. For significant comparisons, least-significant difference post-tests were performed.

3.4. Schizotypy, AVH predisposition and neurological soft signs

A priori hypotheses predicted co-varying effects of handedness and psychological distress, thus these differences between clusters on handedness and psychological distress were controlled using a MANCOVA when examining group effects on NSS variables. Handedness had significant co-varying effects for NES Total score ($F(1, 317) = 17.11$, $p < 0.000$) and NES SCMA subscale ($F(1, 317) = 4.288$, $p = 0.039$). Psychological distress did not have co-varying effects for any NES variables.

No main effects were found for schizotypy or AVH predisposition on NES Total score, SI, MC or SCMA. An interaction effect was observed between schizotypy and AVH predisposition for the NES MC subscale ($F(3, 317) = 4.165$, $p = 0.007$; means in Table 2). To interpret this interaction an Independent Samples *t*-test was used. Those in the High overall Schizotypy cluster with High AVH predisposition expressed significantly more MC NSS compared to those with Low AVH predisposition in the

Table 1
Descriptive statistics (mean, SD) and frequencies of Schizotypy clusters. Significant differences between the groups are reported.

	1. High overall Schizotypy (n = 61)	2. Disorganised Schizotypy dominant (n = 90)	3. Low overall Schizotypy (n = 117)	4. Mixed interpersonal and Cognitive-Perceptual Schizotypy (n = 59)	Test statistic and *p* value	Significant differences?[a]
Sex (M:F)	15:46	31:59	28:89	17:42	$\chi^2 = 3.193$, $p = 0.363$	No
Age	21.59 (7.3)	21.01 (5.4)	21.88 (7.2)	21.42 (7.6)	$F = 0.28$, $p = 0.84$	No
Living arrangements (Parents:Siblings:Partner: Friends:Acquaintences:Alone)	41:3:5:7:1:4	49:5:12:12:5:7	70:4:18:11:8:6	39:1:8:5:1:5	$\chi^2 = 10.101$, $p = 0.813$	No
Verbal intelligence	27.44 (5.3)	27.36 (5.9)	26.84 (5.9)	27.23 (5.7)	$F = 0.307$, $p = 0.82$	No
Health service use (Y:N)	41:20	54:36	76:41	40:19	$\chi^2 = 1.283$, $p = 0.733$	No
Learning disorder (Y:N)	0:61	5:85	1:116	1:58	$\chi^2 = 7.32$, $p = 0.062$	No
SPQ Total	50.48 (7.7)	24.33 (5.8)	11.65 (5.9)	32.15 (5.4)	$F = 553.594$, $p < 0.000$	Yes (1 > 2,3,4;4 > 2,3;2 > 3)
Cognitive-Perceptual SPQ	19.33 (4.5)	7.9 (3.9)	4.84 (3.8)	12.15 (4.6)	$F = 177.139$, $p < 0.000$	Yes (1 > 2,3,4; 4 > 2, 3; 2 > 3)
Interpersonal SPQ	20.49 (4.6)	8.11 (4.1)	4.85 (3.2)	15.98 (4.6)	$F = 252.996$, $p < 0.000$	Yes (1 > 2,3,4; 4 > 2.3; 2 > 3)
Disorganised SPQ	11.49 (2.7)	8.57 (2.2)	2.03 (1.7)	4.9 (1.8)	$F = 337.496$, $p < 0.000$	Yes (1 > 2,3,4; 2 > 3,4; 4 > 3
AVH predisposition	5.95 (2.2)	3.67 (1.9)	2.1 (2.1)	3.95 (2.2)	$F = 47.615$, $p < 0.000$	Yes (1 > 2,3,4;4 > 3; 2 > 3)
Psychological distress GHQ	32.92 (13.2)	21.69 (10.9)	18.03 (11.3)	24.36 (11.1)	$F = 22.898$, $p < 0.000$	Yes (1 > 2,3,4; 4 > 3)
Handedness (Right:Left:Mixed)	Right = 95.1% Left = 1.6% Mixed = 3.3%	Right = 77.8% Left = 21.1% Mixed = 1.1%	Right = 88.9% Left = 7.7% Mixed = 3.4%	Right = 88.1% Left = 5.1% Mixed = 6.8%	$\chi^2 = 22.592$, $p = 0.001$	Yes

SD = standard deviation; N = Number of participants in group; M = male; F = female; Y = yes; N = no; SPQ = Schizotypal Personality Questionnaire (Raine, 1991); AVH = auditory verbal hallucination GHQ = General Health Questionnaire (Goldberg and Hillier, 1979).

[a] Post tests show which clusters differ significantly at the $p = 0.002$ level or below.

same cluster ($t(52.624) = 2.754$, $p = 0.008$; Table 2, superscript [a]; Fig. 1).

Those in the Mixed Interpersonal and Cognitive-Perceptual Schizotypy cluster with High AVH predisposition expressed significantly less MC NSS compared to their Low AVH predisposition counterparts ($t(57) = -2.22$, $p = 0.03$; Table 2, superscript [b]; Fig. 1).

The analysis was then rerun to determine whether differences between AVH predisposition groups were driving the significant effects. Significant differences between schizotypy clusters on NES MC were found for Low AVH predisposition ($F(3, 212) = 4.015$, $p = 0.008$) but not High AVH predisposition ($p = 0.452$). Pairwise Comparisons revealed that those low on AVH predisposition in the Mixed Interpersonal and Cognitive-Perceptual Schizotypy cluster expressed significantly more MC NSS than all other schizotypy clusters within the Low AVH predisposition group (means in Table 2, superscript [c]).

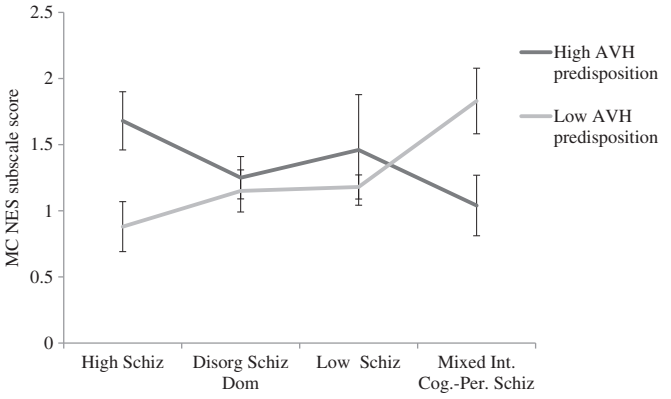

Fig. 1. Mean Motor-Coordination (MC) subscale score (from the Neurological Evaluation Scale (NES)) for each Schizotypy cluster, with clusters split into High and Low Auditory Verbal Hallucination (AVH) predisposition. Error bars represent standard error.

4. Discussion

The present study investigated the effect of trait schizotypy and state AVH predisposition on the expression of NSS. In keeping with previous literature (Barrantes-Vidal et al., 2003), cluster analysis revealed four clusters of participants according to their responses on the SPQ dimensions: High overall Schizotypy, Disorganised Schizotypy dominant, Mixed Interpersonal and Cognitive-Perceptual Schizotypy and Low overall Schizotypy. Those with mixed handedness were more likely to be found in the Mixed Interpersonal and Cognitive-Perceptual Schizotypy group, whilst those with left handedness were more likely in the Disorganised Schizotypy dominant group. Handedness was a significant covariate for NES Total and SCMA scores, however no group differences were found. The data suggests there is not a simple relationship between schizotypy, AVH and NSS. Those in the High overall Schizotypy cluster with High AVH predisposition expressed significantly greater MC NSS compared to those in the same cluster with Low AVH predisposition, with this relationship reversed in the Mixed Interpersonal and Cognitive-Perceptual Schizotypy group. Contrary to predictions there was no main effect of schizotypy clusters for NSS expression. State psychological distress did not significantly co-vary for the expression of NSS, although the schizotypy groups did report higher distress, with distress highest in the High overall Schizotypy group.

Consistent with expectations those in the High overall Schizotypy cluster with co-occurring High AVH predisposition expressed significantly greater MC NSS compared to those in the same schizotypy cluster but with Low AVH predisposition. Surprisingly this interaction was reversed for the Mixed Interpersonal and Cognitive-Perceptual Schizotypy cluster. Those in this cluster with Low AVH predisposition expressed significantly greater MC NSS compared to their High AVH predisposition counterparts. The link between motor coordination deficits and psychosis has been documented at all stages of the psychosis continuum, from prospective studies of children who go on to develop schizophrenia (Schiffman et al., 2009), adolescents with high levels of schizotypy (Mittal et al., 2008), offspring of schizophrenia patients as well as medication-naïve schizophrenia patients (Wolff and O'Driscoll, 1999). The current results extend these findings of movement abnormalities to a more specific and subtle form of motor coordination impairment in the form of neurological soft signs. Yet whilst a link appears to exist between schizotypy and motor coordination NSS, the association with state factors such as AVHs does not appear simple. MC NSS were associated with high overall schizotypy and co-occurring AVH predisposition, suggesting multiple "hits" are necessary to result in motor coordination abnormalities at the high end of schizotypy. Additionally our results indicate that higher levels of Interpersonal schizotypy when combined with moderate levels of Cognitive-Perceptual schizotypy (as in the Mixed Interpersonal and Cognitive-Perceptual Schizotypy cluster) may be sufficient in the expression of MC NSS without the additional "hit" of AVH predisposition. Gross et al. (2014) reported that the Interpersonal subscale of the SPQ does not encapsulate negative schizotypy as well as the Cognitive-Perceptual subscale taps positive schizotypy. Given this limitation, the current findings highlight the utility of the cluster approach in being able to account for elevations on more than one schizotypy dimension. These results also support consistent findings in the literature linking negative symptoms of schizophrenia to elevated rates of NSS (e.g. Mohr et al., 1996; Arango et al., 2000), which have been replicated with negative schizotypy (i.e. Bollini et al., 2007; Kaczorowski et al., 2009; Theleritis et al., 2012). Negative schizotypy has been associated with lower

Table 2
Means (standard error of the mean) of interaction effects between schizotypy clusters and AVH predisposition groups for Neurological Evaluation Scale (NES) total and subscale scores.

		NES Total	NES SI	NES MC	NES SCMA
High overall Schizotypy	High AVH predis.	10.45 (0.59)	2.2 (0.19)	**1.68 (0.22)**[a]	0.98 (0.19)
	Low AVH predis.	9.76 (1.11)	2.65 (0.31)	**0.88 (0.19)**[ac]	0.47 (0.19)
	Total	10.28 (0.62)	2.48 (0.22)	1.2 (1.7)	0.68 (0.19)
Disorganised Schizotypy dominant	High AVH predis.	9.86 (0.96)	2.11 (0.27)	1.25 (0.16)	0.68 (0.27)
	Low AVH predis.	10.02 (0.51)	2.34 (0.19)	**1.15 (0.16)**[c]	0.77 (0.15)
	Total	9.79 (0.47)	2.22 (0.17)	1.21 (0.13)	0.71 (0.14)
Low overall Schizotypy	High AVH predis.	9.62 (1.2)	2.54 (0.56)	1.46 (0.42)	0.77 (0.26)
	Low AVH predis.	9.81 (0.41)	2.51 (0.14)	**1.18 (0.09)**[c]	0.93 (0.12)
	Total	9.82 (0.62)	2.49 (0.22)	1.35 (0.17)	0.89 (0.18)
Mixed interpersonal and Cognitive-Perceptual Schizotypy	High AVH predis.	8.88 (0.76)	2.17 (0.27)	**1.04 (0.23)**[b]	0.58 (0.16)
	Low AVH predis.	12.3 (0.78)	2.69 (0.27)	**1.83 (0.25)**[bc]	1.31 (0.28)
	Total	10.54 (0.55)	2.44 (0.19)	1.43 (0.16)	0.94 (0.16)

SI = Sensory Integration, MC = Motor Coordination, SCMA = Sequencing of Complex Motor Acts, AVH predis. = Auditory Verbal Hallucination predisposition. Significant effects ($p < 0.05$) indicated by bold font type. Significant differences between High and Low AVH predis. Groups within the High overall Schizotypy cluster denoted by [a]; Significant differences between High and Low AVH predis. Groups within the Mixed Interpersonal and Cognitive-Perceptual Schizotypy cluster denoted by [b]; Significant differences between schizotypy clusters within the Low AVH predis. Group denoted by [c].

functional outcomes (Cohen and Davis, 2009), suggesting this schizotypy dimension in particular may be an indicator of need for care in itself (Lin et al., 2013). State risk factors alone have been reported to have low specificity in accurately predicting conversion to psychosis (Debbané and Barrantes-Vidal, 2015). Our findings demonstrate the importance of considering different trait dimensions as well as integrating both trait and state psychosis risk factors.

It was also predicted that schizotypy clusters would differ significantly in their expression of NSS, however this hypothesis went unsupported. Our predictions were based on previous correlational research (e.g. Chan et al., 2010b; Mechri et al., 2010; Theleritis et al., 2012). Since NSS are understood as neurodevelopmental markers of psychiatric risk, it follows that expression of NSS should be the result of high schizotypy in combination with other state features of risk. Other studies have demonstrated limited or no differences in neurological soft sign expression due to schizotypy alone (e.g. Obiols et al., 1999; Barrantes-Vidal et al., 2003; Bollini et al., 2007).

When psychological distress was considered in the analysis it was not a significant covariate between schizotypy and AVH predisposition for NSS expression. Previous studies utilizing community samples (healthy first-degree relatives of schizophrenia patients) have shown interview-assessed state psychopathology (axis 1 psychiatric illness) to increase NSS in those with high schizotypy (e.g. Keshavan et al., 2008; Prasad et al., 2009). Since psychopathology is by definition more severe than state distress, it may be that the degree of functional impairment focused on in the current study was not of a sufficient threshold to impact upon the expression of neurological soft signs.

Demographic characteristics may have contributed to some of the non-significant findings in this study, therefore the homogeneity of a University-educated sample is considered a limitation. Given that a large percentage of schizotypy research in this area utilizes a University-based sample (e.g. Barkus et al., 2006; Chan et al., 2010b; Kaczorowski et al., 2009), it would be extremely beneficial for future research to determine the extent to which tertiary level education impacts upon psychosis risk variables. Another factor that limits the interpretability of the present findings is the use of a cross-sectional design, given that psychosis high-risk variables are known to change over time (especially during adolescence/early adulthood; Shah et al., 2013). Although the present study provides evidence that trait schizotypy and state AVH predisposition interact for the expression of motor neurodevelopmental risk, it cannot be said whether greater NSS are a result of this interaction, or whether other co-occurring variables are contributing, such as cognitive reserve (i.e. Urbanowitsch et al., 2015) or comorbidity with obsessive-compulsive symptoms (i.e. Tumkaya et al., 2012). Future research which tracks trait and state psychosis risk variables over time will help to disentangle more influential "hits" associated with illness transition, from less influential but comorbid psychosis risk factors.

Although still in its infancy, research is beginning to shift from a high clinical risk approach of psychosis vulnerability to a more encompassing framework; integrating developmental traits such as schizotypy and subclinical phenomena (including AVH predisposition and distress) (Debbané and Barrantes-Vidal, 2015). The present study reports pertinent findings for the interaction between trait schizotypy and state AVH predisposition in the expression of motor NSS. When combined with previous results, the current findings provide support for the existence of abnormalities in motor coordination for individuals on the psychosis continuum. Future research which goes another step further to longitudinally investigate the interaction between trait and state psychosis risk factors may more specifically distinguish the trajectory and severity of motor NSS as individuals progress along the continuum.

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